20000822 221

EEDP-01-11
March 1988

Environmental Effects of Dredging
Technical Notes

CONTAMINANT MODELING

PURPOSE: This note provides initial information on contaminant models that are potentially applicable to situations where the presence of toxic materials in sediments complicates Corps of Engineers (CE) dredging activities.

BACKGROUND: Public concern about environmental contamination and increased regulatory requirements by local, State, and other Federal agencies mandate that Corps managers comprehensively address questions related to the presence of contaminants in dredged material. Modeling, in conjunction with field and laboratory evaluations, provides a valuable tool for answering questions raised when the presence of contaminated sediments complicates dredging operations. The emphasis by regulatory agencies on the use of models is steadily increasing. As a result, CE managers must be adequately informed about availability, capability, and applicability of various contaminant fate models.

ADDITIONAL INFORMATION OR QUESTIONS: Contact the author, Ms. Sandra L. Bird, commercial or FTS, (601) 634-3783; Mr. Mark Dortch, (601) 634-3517; or the manager of the Environmental Effects of Dredging Programs, Dr. Robert M. Engler, (601) 634-3624.

Background

As the need for applying contaminant fate models in the evaluation of dredging-related problems increases, CE managers must be familiar with the applicability and limitations of these models. Industry, academia, and government agencies have developed numerous contaminant fate models, many of which are neither easily accessible nor adequately documented and supported. This discussion focuses on five readily available, well-documented models--MINTEQ, EXAMS, MEXAMS, HSPF, and TOXIWASP. Characteristics of these models are summarized in Table 1. These five models are supported by the US Environmental Protection Agency (USEPA), which also continually refines and upgrades them. Acceptance and support of these models by this national regulatory agency increases the likelihood that one or more may be recommended to CE

US Army Engineer Waterways Experiment Station, Environmental Laboratory
PO Box 631, Vicksburg, Mississippi 39180-0631

Table 1

Summary of USEPA Contaminant Model Characteristics

Model	Chemicals	Aquatic Systems	Spatial Resolution	Temporal
MINTEQ	Metals	All	Zero-dimensional (0D) (mixed reactor)	Steady-state
EXAMS	Organics	Lake, river, tidally averaged estuary	Variable (0,1,2,3D)	Time-varying concentration with quasi-steady flow and loading
MEXAMS	Metals	Lake, river, tidally averaged estuary	Variable (0,1,2,3D)	Time-varying concentration with quasi-steady flow and loading
HSPF	Organics	River, run-of-river reservoir	1D longitudinal	Fully time-varying
TOXIWASP	Organics	All	Variable (0,1D,2D,3D)	Fully time-varying

managers for use in permit applications. A subsequent WES technical report will be prepared to discuss in detail the use of these USEPA models, and a variety of other contaminant fate models, in the evaluation of dredging-related problems.

USEPA Contaminant Fate Models

MINTEQ (Felmy, Girvin, and Jenne 1984) calculates aqueous geochemical phase equilbria for seven priority metal pollutants (arsenic, cadmium, copper, lead, nickel, silver, and zinc) using environmental variables, including pH, ionic strength, and temperature. MINTEQ is a mixed reactor or zero-dimensional model, i.e., there is no spatial resolution of the system modeled. MINTEQ is strictly an equilibrium model and cannot provide information about time-varying processes. However, MINTEQ does give an estimate of aqueous speciation and predicts the removal from solution of different metallic species by adsorption and precipitation. Toxicity of a metal varies with the form of the metal, so information about the proportion of each species present, as well as total metal concentration, is important in evaluating

environmental impacts. An extensive thermodynamic data base for the seven metals MINTEQ simulates is included in the model package. An interactive preprocessor is available with MINTEQ to aid the user in setting up input data sets.

In dredging-related applications, MINTEQ can be used in assessing potential increases in toxicity, mobility, and bioavailability of metals in dredged materials at a disposal site, particularly when the chemical environment at the disposal site is significantly different from the dredging site. Additionally, MINTEQ can effectively aid in assessing the behavior of metals entering receiving waters from upland disposal facility runoff or water released from confined aquatic facilities.

EXAMS, the Exposure Analysis Modeling System (Burns and Cline 1985), a steady-flow compartment model, calculates the concentration and distribution of organic compounds in a system under a given pollutant load; EXAMS further determines the persistence of compounds in the system after the loading is removed. This model is applicable to systems where an assumption of constant pollutant loading and steady flow is reasonable over a period of a few weeks. Spatial resolution in one, two, or three dimensions can be obtained with EXAMS, depending on the number and arrangement of the compartments. EXAMS requires input of flow distribution within the system and calculates flow through the compartments based on volume conservation. EXAMS calculates dissolved and sediment-bound contaminant concentrations in both the water column and benthic layers. A major technical strength of this model is its handling of chemical kinetic processes such as hydrolysis, photolysis, microbial degradation, and volatilization. EXAMS has been designed so it can be easily applied for screening the behavior of numerous organic compounds and can be run interactively for rapid evaluation of scenarios. EXAMS is user friendly and provides on-line "help" to explain command options and input requirements.

EXAMS could be useful in screening for the presence of various contaminants in the sediments of lakes or streams with known or suspected loadings or for calculating contaminant concentrations downstream from a disposal facility. Additionally, EXAMS may have application in evaluating action/no-action alternatives where steady flow and loading assumptions are valid. EXAMS could be applied in estuarine applications where tidally averaged values for the flow are considered.

Limitations in handling suspended solids and sediment-water interactions

diminish EXAMS' usefulness in analyzing many dredging-related problems. EXAMS does not simulate solids concentration in the water column; i.e., solids concentration must be supplied as input to the model. EXAMS does not include solids settling/resuspension processes. Net exchange of contaminants between the bed solids and suspended solids and between the water column and pore water is lumped into a single exchange coefficient. Loss of contaminants through burial is not accounted for in this model.

MEXAMS, Metal Exposure Analysis Modeling System (Felmy et al. 1982), combines the metal equilibrium model of MINTEQ with the transport structure of EXAMS, allowing calculation for a constant loading of the steady-state distribution of heavy metal species throughout a water body and persistence in the system after removal of the loading. Applicability of MEXAMS is similar to EXAMS except it simulates the metals in the MINTEQ data base (arsenic, cadmium, copper, lead, nickel, silver, and zinc) rather than organic compounds.

HSPF, Hydrologic Simulation Program - FORTRAN (Donigan et al. 1984), a one-dimensional model for nontidal rivers and unstratified lakes, is coupled with a watershed hydrologic model and nonpoint-source runoff algorithms. HSPF simulates organic pollutants in a time-varying mode. Sediment transport is calculated for three particle sizes (sand, silt, clay). HSPF has been used to evaluate best management practices for controlling nonpoint-source pollution from surface runoff, i.e., to determine impacts on receiving water quality from changes in watershed land use. This model may prove useful in examining effects of different watershed land use options on sediment quality or on sediment contributions to water quality problems that could impact dredging operations.

TOXIWASP, Toxics Water Analysis Simulation Program (Ambrose, Hill, and Mulkey 1983) is a time-varying, multidimensional, box-type model for simulating transport and fate of toxic organic chemicals in rivers, lakes, estuaries, or coastal waters. TOXIWASP segments can be arranged in a zero-, one-, two-, or three-dimensional configuration to achieve any required spatial resolution. Time-varying or steady-state flows can be used in WASP simulations and must be supplied to the model as input. For complex multidimensional water body applications, a separate hydrodynamic model simulation would probably be required in conjunction with the TOXIWASP applications. Three different size classes of sediment and contaminant concentration for each class are simulated in the most recent version of the model. TOXIWASP simulates multiple bed

layers and allows net deposition or erosion of the bed surface and removal of contaminants from the system through burial. TOXIWASP incorporates chemical kinetics similar to EXAMS. As in EXAMS and HSPF, numerous parameters related to environmental and pollutant characteristics are required.

Although setting up TOXIWASP may prove data intensive and time consuming, the model's flexibility, including the ability to perform time-varying calculations, to simulate multiple sizes of suspended sediment and contaminant concentrations associated with each fraction, and to simulate a dynamic bed and loss of contaminant through burial, makes its potential great in dredging-related activities. While TOXIWASP is designed for organics, transport of metals, without speciation, could be performed within the model's framework. TOXIWASP should also be applicable in evaluating the action/no-action alternatives; i.e., predicting the effects of dredging or not dredging based on ambient conditions. TOXIWASP could be applied to evaluate the impacts of different dredging options on water quality. Furthermore, TOXIWASP is applicable in evaluating the impact of disposal operations on ambient conditions. For example, if linked to system hydrodynamics, TOXIWASP could be used to evaluate the impacts of a disposal site on ambient water and sediment quality. TOXIWASP could be used to simulate operations of a confined disposal facility to estimate return-flow concentrations from the site under different operational regimes.

In addition to the USEPA models, a variety of other models exist to model the fate of contaminants in aquatic systems. Several are capable of time-varying one- or two-dimensional system hydrodynamics, sediment transport, and first-order contaminant loss. Others make simplifying assumptions such as steady flow or mixed reactors to facilitate ease of application. Others consider partitioning/uptake of contaminants in the biota as well as the water column and sediment. Some trace biomagnification of contaminants through the food chain. Several models calculate concentration distributions through a series of sediment layers in the bed. PC-based spreadsheet type analytical models show utility for quick estimates of contaminant concentrations. A comprehensive discussion of available contaminant fate models and their potential application to dredging-related problems will be presented in a WES technical report scheduled for completion in 1988.

References

Ambrose, R. B., Jr., Hill, S. I., and Mulkey, L. A. 1983. "Users' Manual for the Chemical Transport and Fate Model Toxiwasp — Version I," 600/3-83/005, US Environmental Protection Agency, Athens, Ga.

Burns, L. A., and Cline, D. M. 1985. "Exposure Analysis Modeling System: Reference Manual for Exams II," 600/3-85/038, US Environmental Research Laboratory, Athens, Ga.

Donigan, A. S., Imhoff, J. C., Bicknell, B. R., and Kittle, J. L. 1984. "Application Guide for Hydrological Simulation Program — FORTRAN (HSPF)," 600/3-84/065, US Environmental Protection Agency, Athens, Ga.

Felmy, A. R., Brown, S. M., Onishi, Y., Argo, R. S., and Yabusaki, S. B. 1982. "MEXAMS — The Metals Exposure Analysis Modeling System," 68/03/3089, US Environmental Protection Agency, Athens, Ga.

Felmy, A. R., Girvin, D. C., and Jenne, E. A. 1984. "MINTEQ — A Computer Program for Calculating Aqueous Geochemical Equilibria," 600/3-84/032, US Environmental Protection Agency, Athens, Ga.

INTERNET DOCUMENT INFORMATION FORM

A . Report Title: CONTAMINANT MODELING

B. DATE Report Downloaded From the Internet: 08/15/00

C. Report's Point of Contact: (Name, Organization, Address, Office Symbol, & Ph #):
US Army Engineer Waterways Experiment Station
Environmental Laboratory
PO Box 631
Vicksburg, Mississippi 39181-0631

D. Currently Applicable Classification Level: Unclassified

E. Distribution Statement A: Approved for Public Release

F. The foregoing information was compiled and provided by:
DTIC-OCA, Initials: __LF__ Preparation Date 08/21/00

The foregoing information should exactly correspond to the Title, Report Number, and the Date on the accompanying report document. If there are mismatches, or other questions, contact the above OCA Representative for resolution.